Row-Column Addressed 2-D CMUT Arrays with Integrated Apodization

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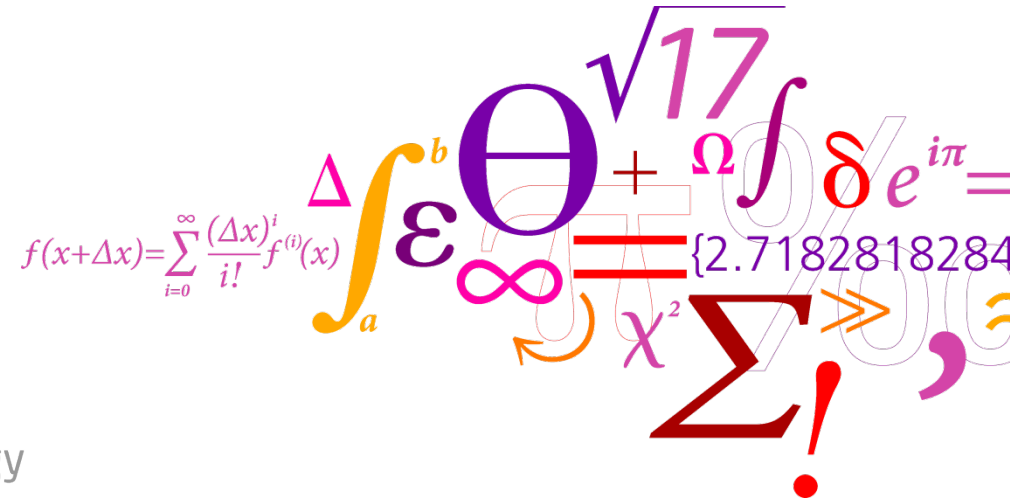


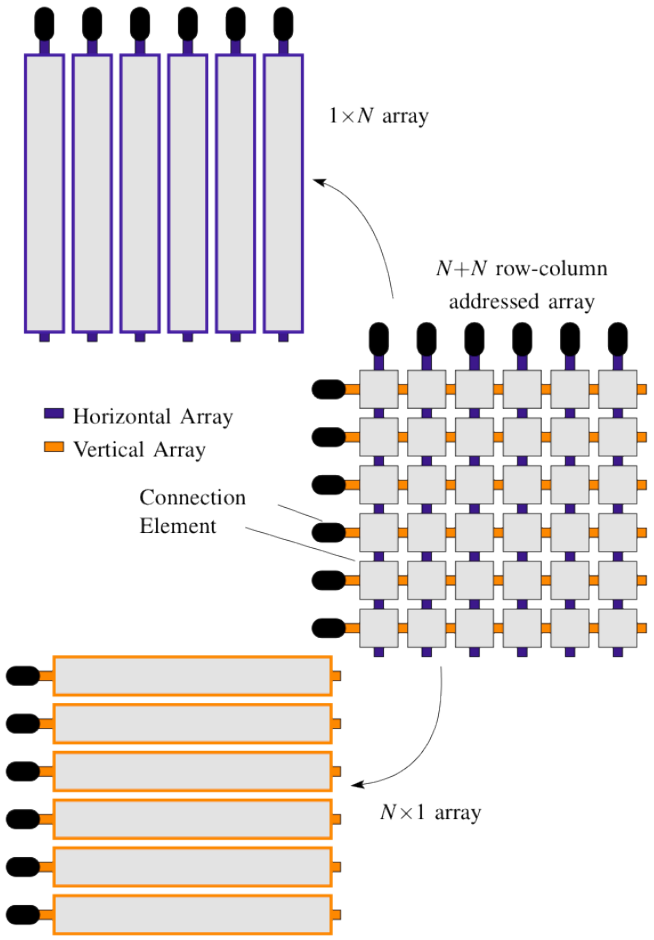
DTU Nanotech
Department of Micro- and Nanotechnology

Agenda

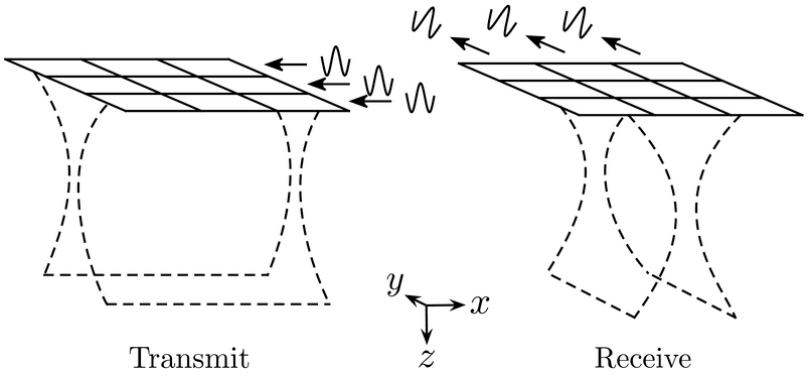
- Background and motivation
- CMUT row-column arrays with integrated apodization
- 3-D imaging experiments
- Conclusion

Background and motivation

Row-Column addressing

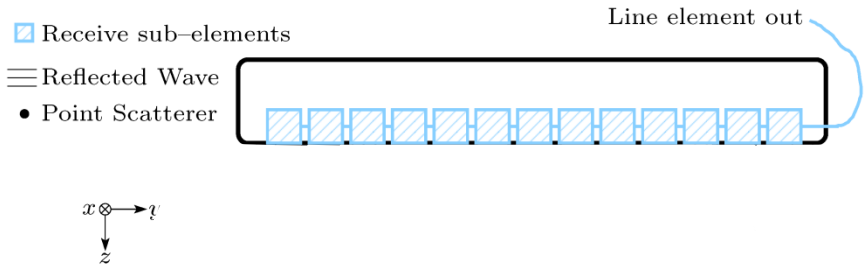


- The 2-D array is essentially comprised of two orthogonal 1-D arrays.
- Transmit focusing is performed in a line in one dimension, while receive focusing is performed in a line in the orthogonal dimension.
- Connections: $N^2 \Rightarrow 2N$
- High frame rate, high energy



Edge effects

- The elements span the whole length of the array
- No electronic control along the length of the elements
- Edge effects become prominent



Point scatterer

These edge waves create additional ”ghost” echoes that compromise the image quality!

Figure from: M. F. Rasmussen et al. *3D ultrasound imaging performance of a row-column addressed 2D array transducer: a simulation study*, Proc. of SPIE Vol. 8675, 2013

Motivation and purpose

Pros: High resolution, real-time 3-D imaging can be performed with row-column addressed arrays with low channel count

Cons: The long elements inherently produce edge effects, which compromise the image quality. No electronic apodization is possible along the length of the elements

Solution: Apodization must be **integrated** in the transducer itself if row-column arrays are to produce high quality 3-D images

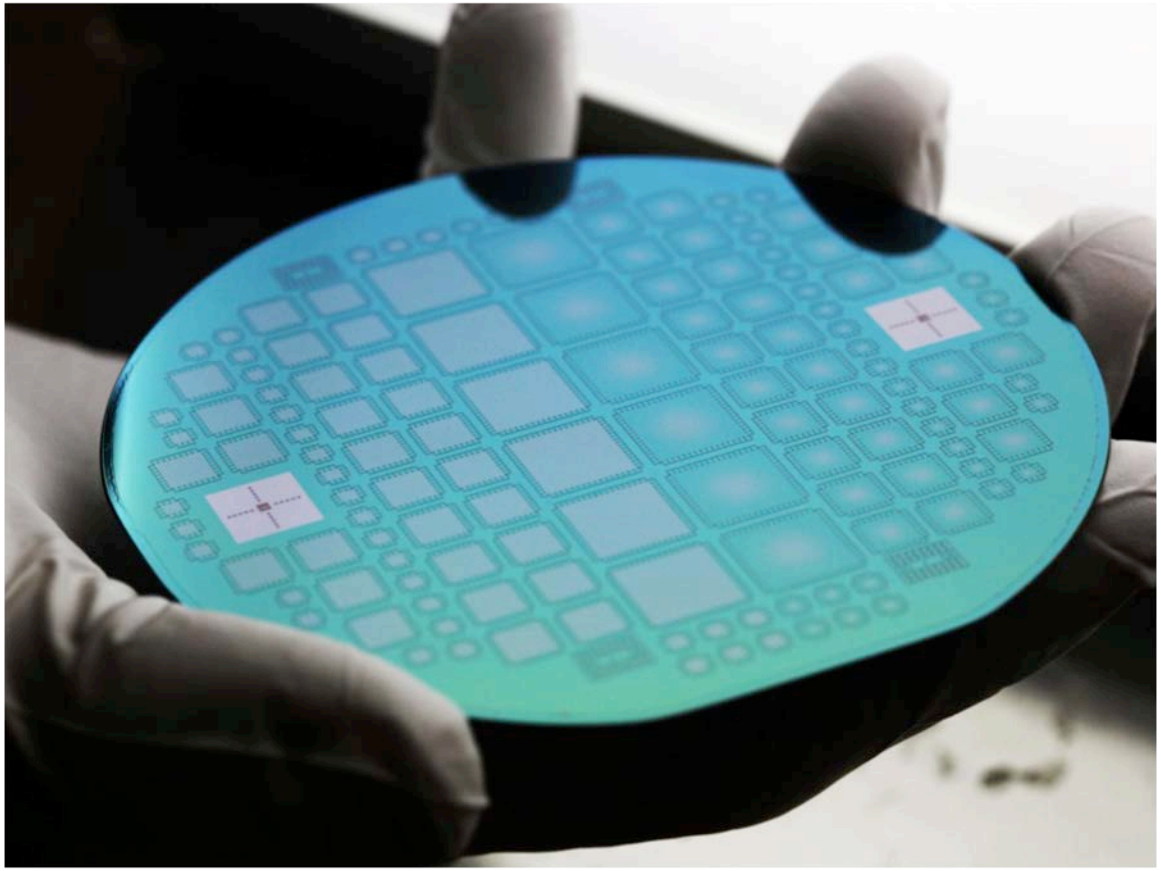
CMUT technology provides a platform for such an integrated apodization

CMUT row-column arrays with integrated apodization

Fabrication: Process flow

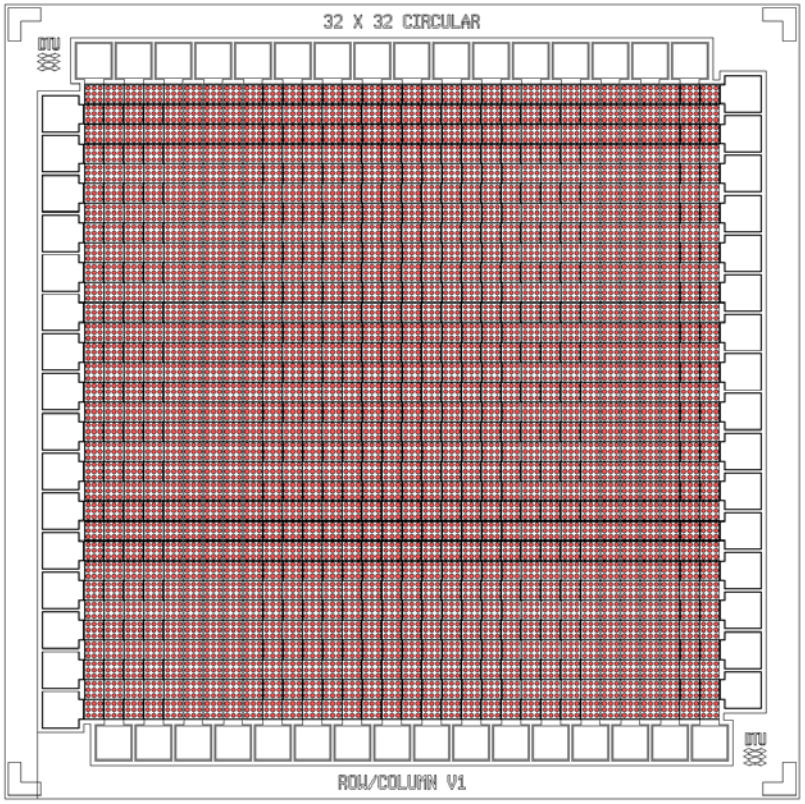
a)

Fabrication:
32+32 row-column arrays

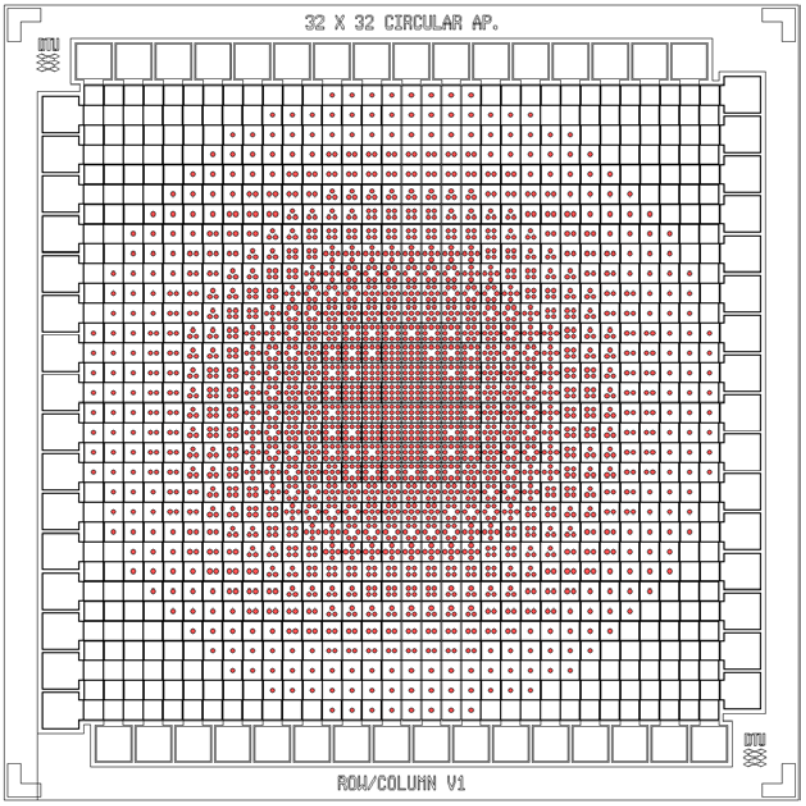


Validation of integrated apodization: Transducer layout

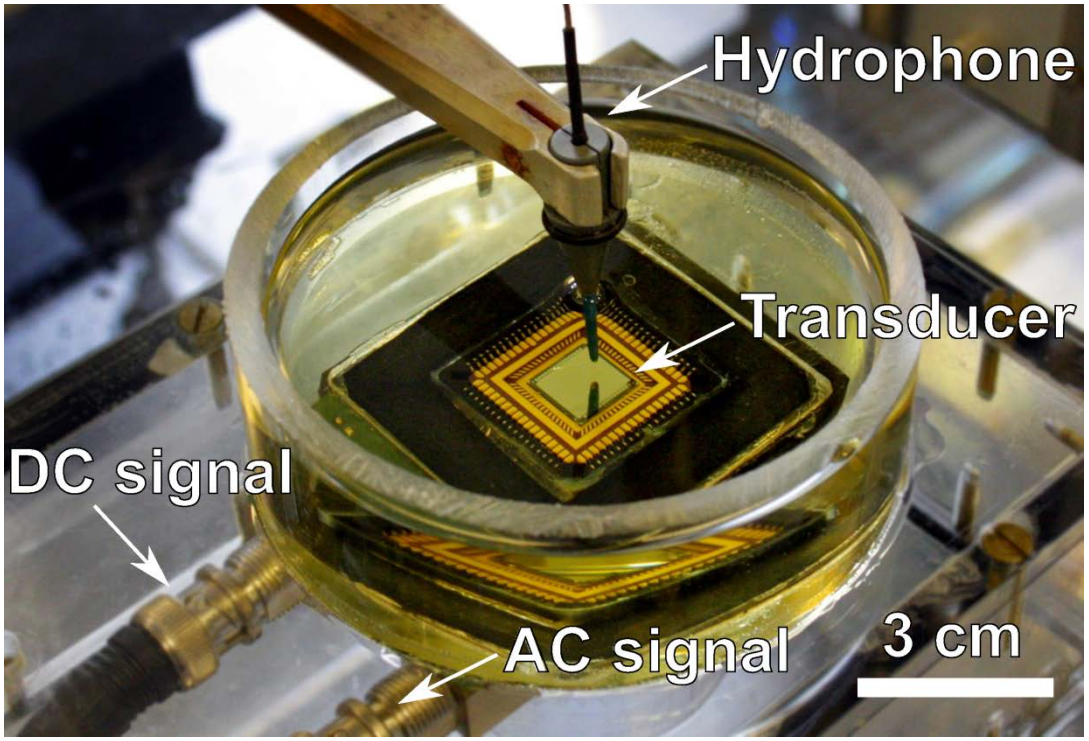
Standard 32+32 row-column array



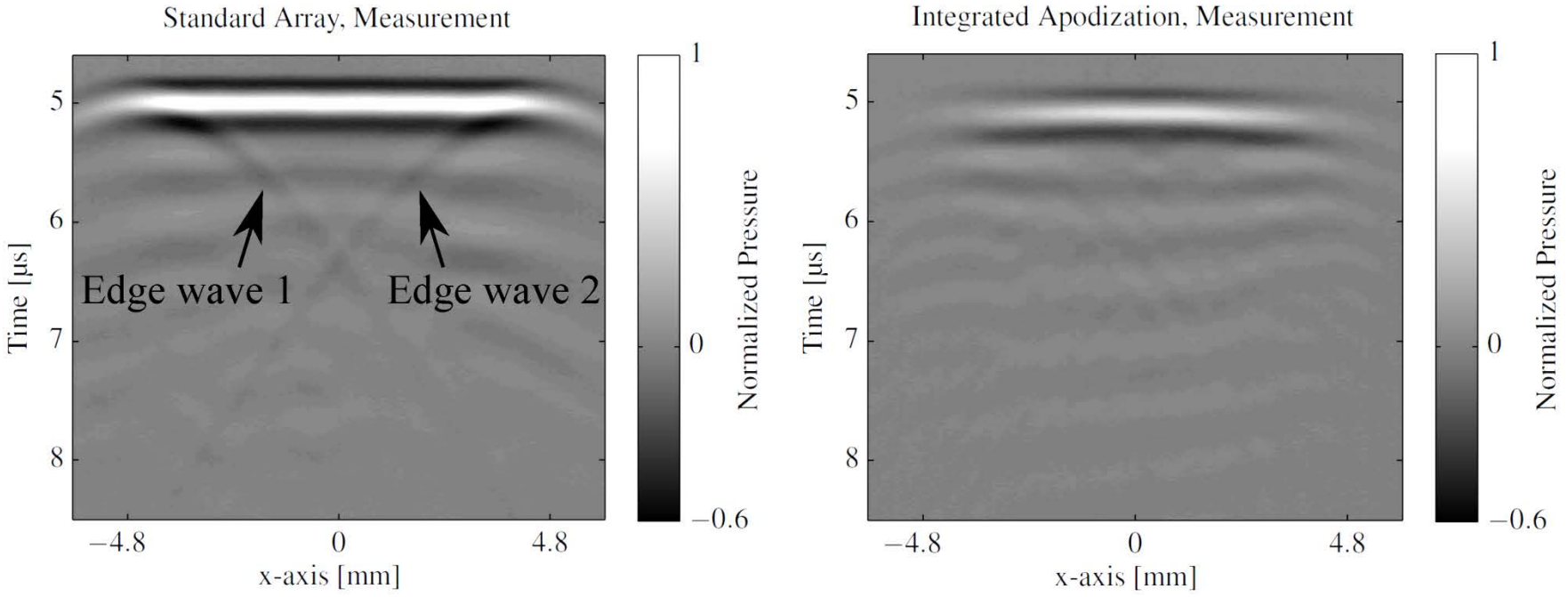
Hann apodized 32+32 row-column array



Validation of integrated apodization: Experimental setup



Validation of integrated apodization: Result



The total energy of the waves after the main wave is reduced by 34 %

Result of first iteration of integrated apodization

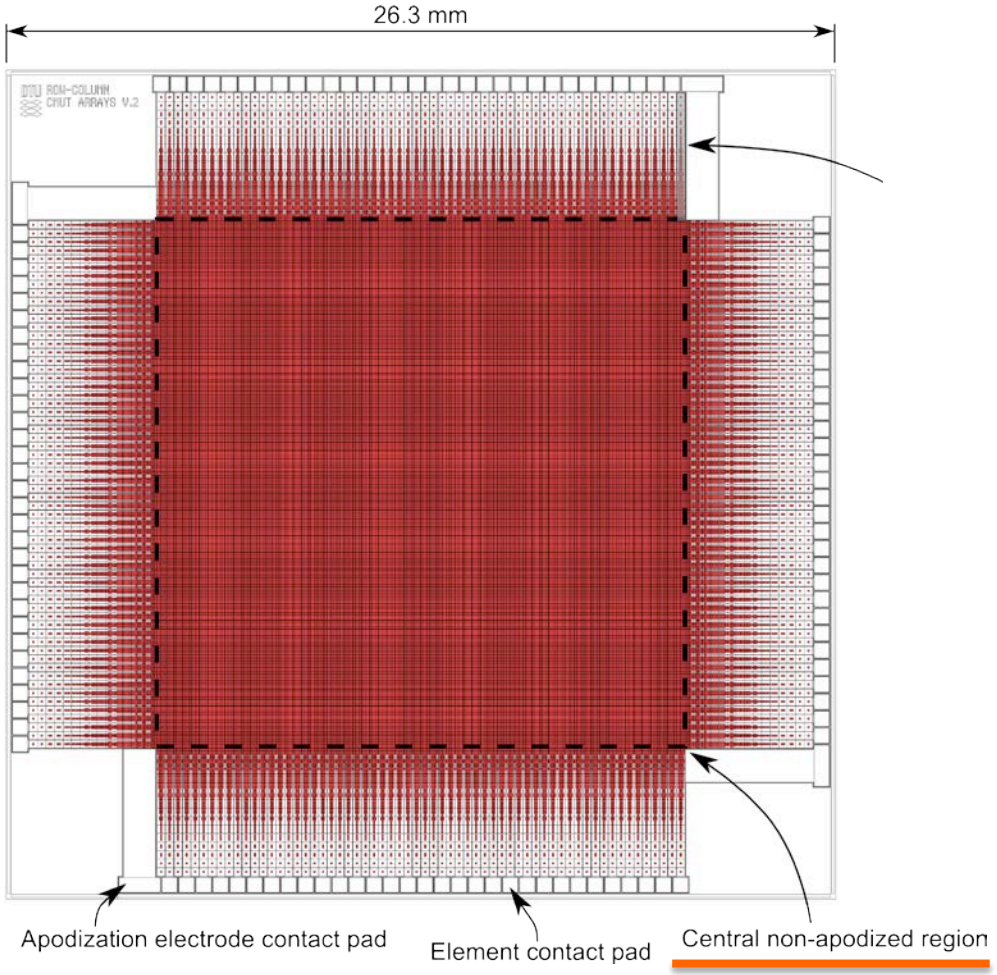
- Apodization can be integrated in the transducer using CMUT technology
- It effectively mitigates the problem of edge waves
- The Hann apodization reduces the energy emitted from the array

The concept of the integrated apodization works, but the layout must be re-designed to avoid reduction of the emitted energy

Integrated apodization for 3-D imaging: 64+64 Layout

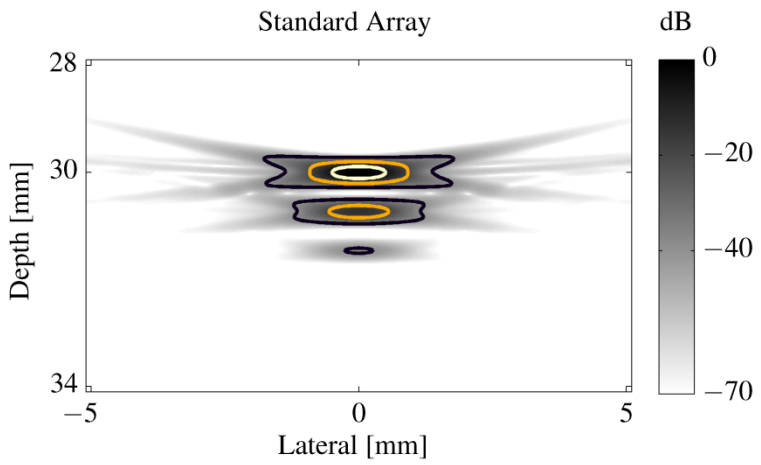
- 64 row channels
- 64 column channels
- 4 channels provide bias for the apodized regions
- The central region is not apodized

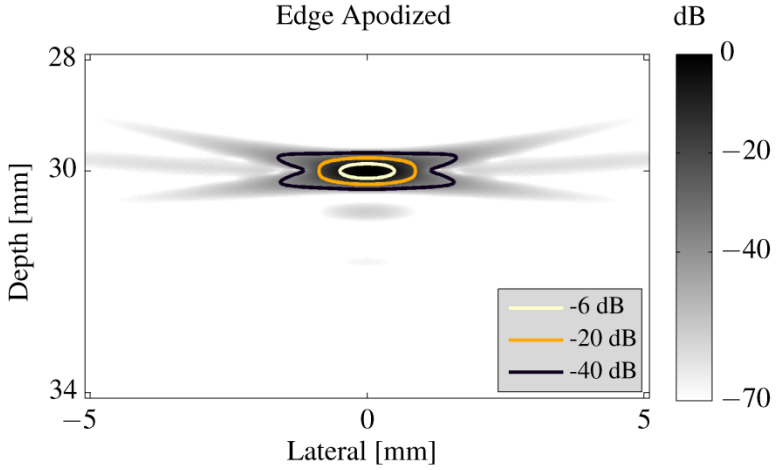
The apodization is decoupled from the central transducer aperture



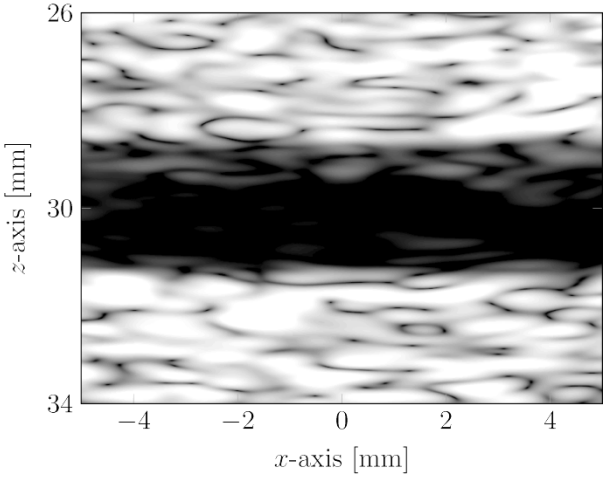
Integrated apodization for 3-D imaging: Effect of apodization on image quality

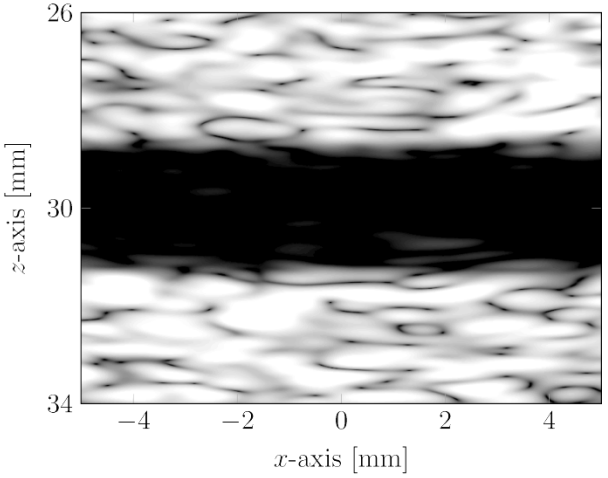
Point scatterer





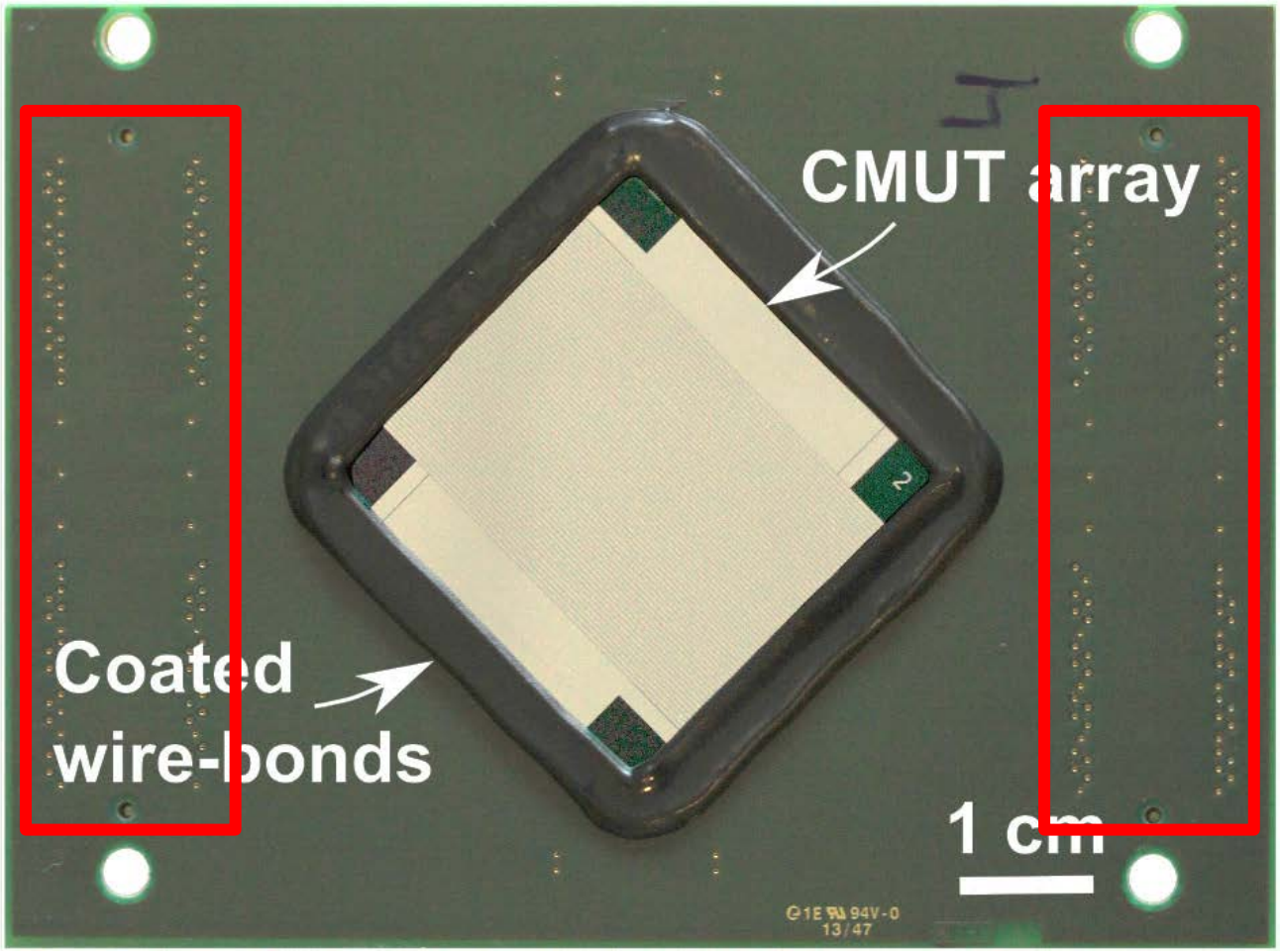
Vessel phantom



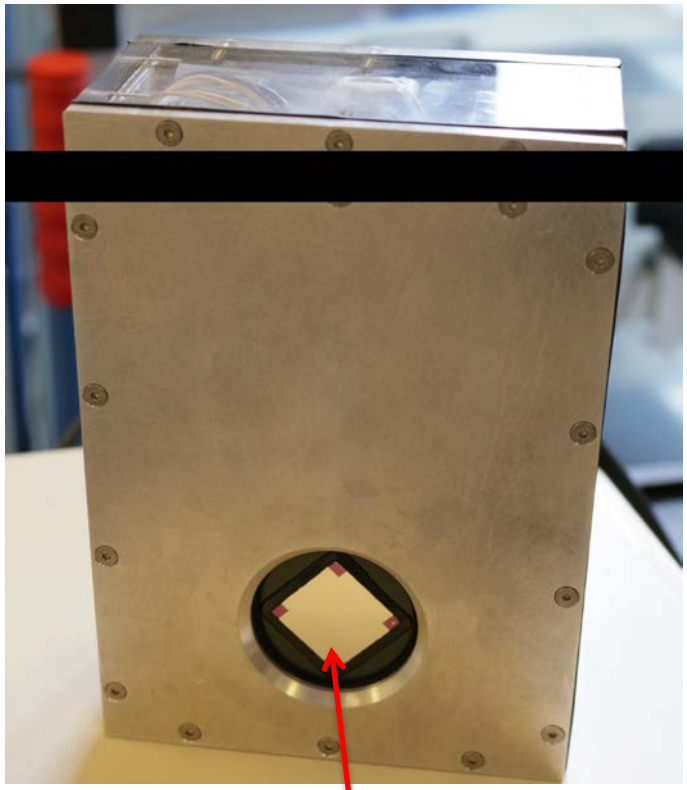


3-D imaging experiments

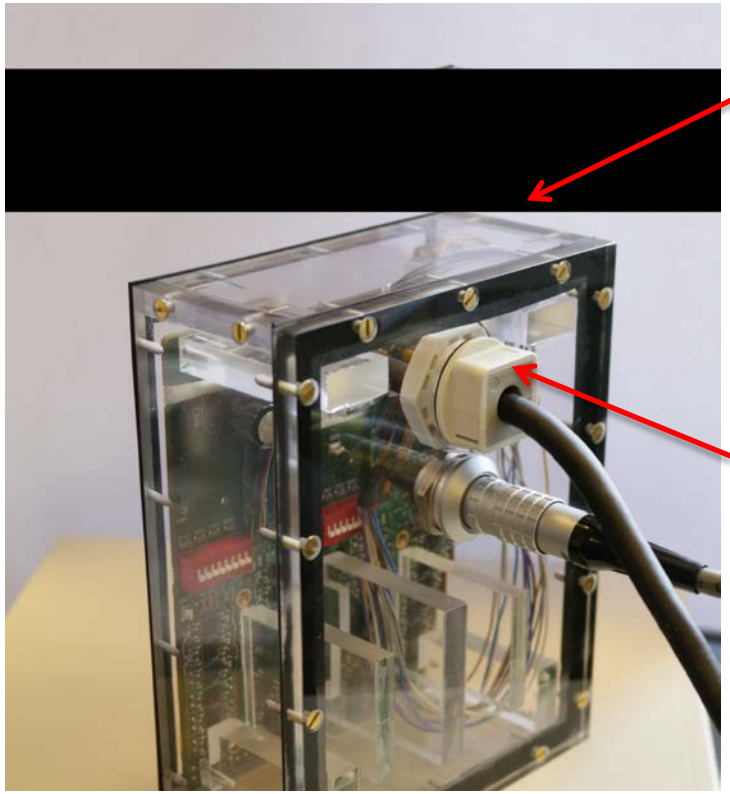
Mounting and wire-bonding



Mechanical fixture and electronics



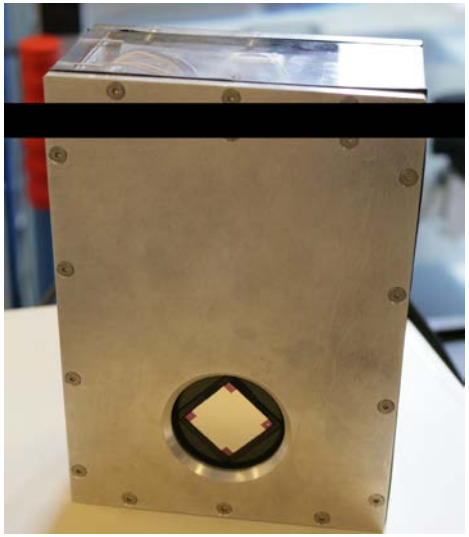
CMUT array

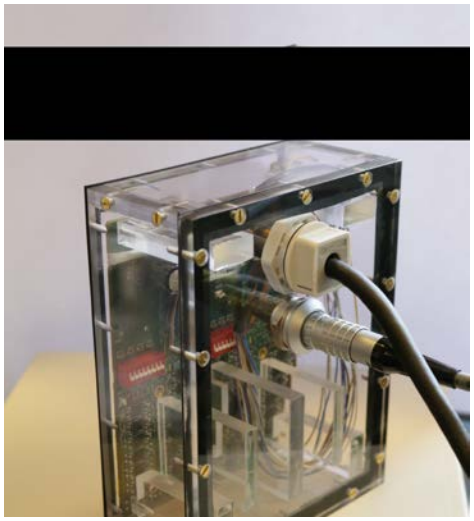


Connector cable

DC voltage supplies

Mechanical fixture and electronics

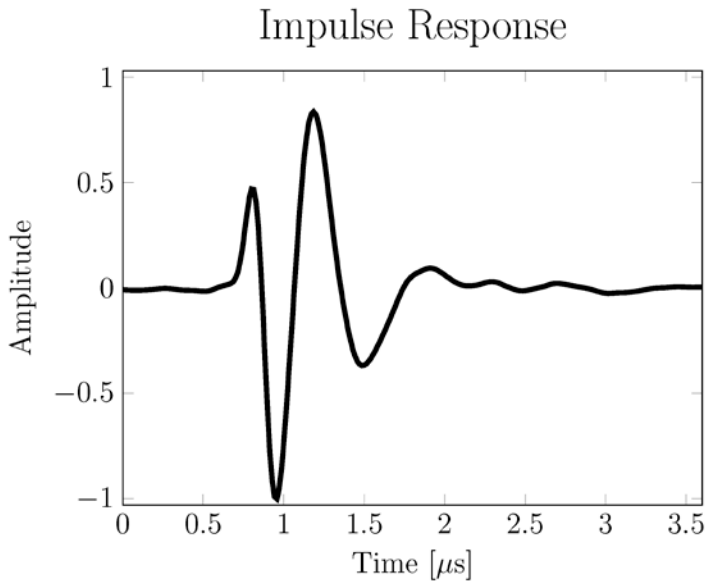


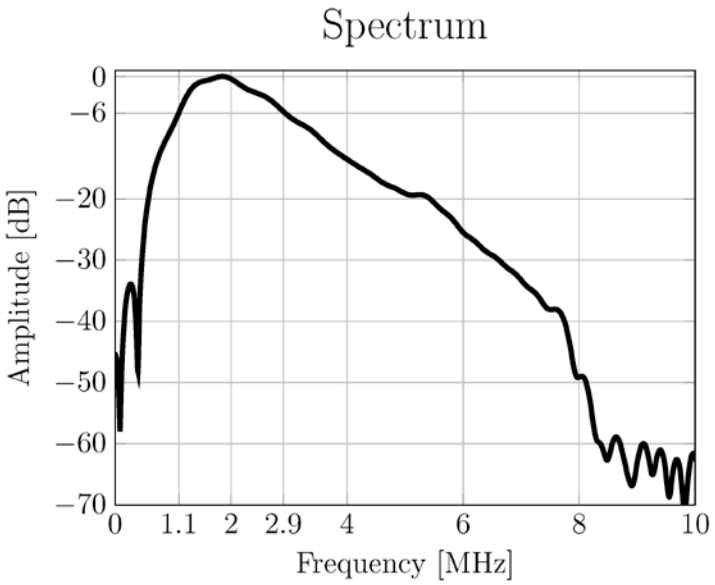


- Pre-amplifiers in the receive circuit (9 dB voltage gain)
- All 128 channels can transmit and receive simultaneously
- The Synthetic Aperture Real-time Ultrasound Scanner (SARUS) is used to transmit and receive the signals

Acoustical characterization

Parameter	Mean	Std	Unit
Center frequency in immersion	2.72	0.26	MHz
−6 dB fractional bandwidth	80	5	%
Transmit pressure peak-to-peak	61.4	7.6	kPa
Sensitivity at 2.5 MHz	0.212	0.063	µV/Pa
Pull-in voltage	100	2	V
DC bias	80	-	V
AC excitation amplitude	50	-	V





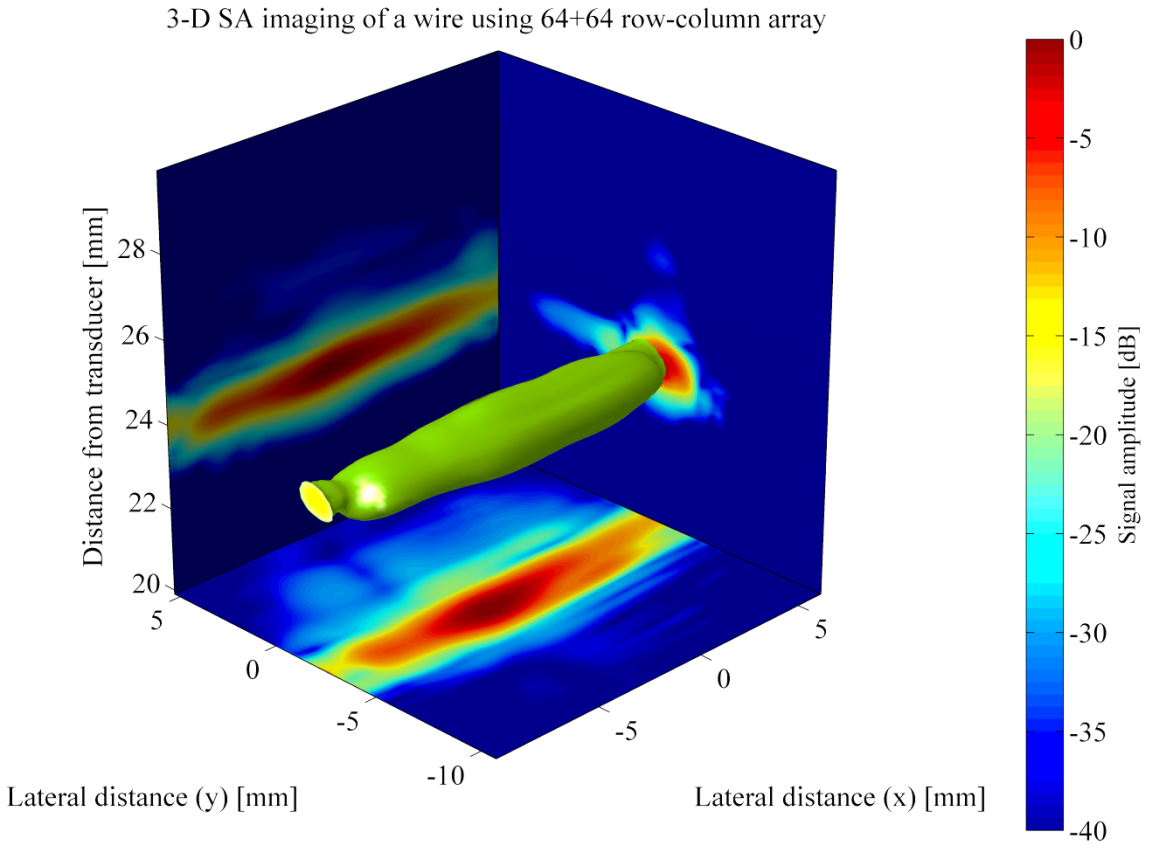
3-D imaging of wire (0.3 mm diameter)

- Full synthetic aperture imaging (single element emission) is employed
- 62 transmit events
- 62 elements used in receive

- -6 dB lateral FWHM:

  1.91 mm
- -6 dB axial FWHM:

  0.71 mm



Conclusion

- Row-column addressing greatly reduces the number of channels needed for performing real-time, 3-D imaging
- Row-column addressed arrays produce edge waves due to the lack of electronic control along the long elements
- Apodization can be integrated in the transducer using CMUT technology
- This apodization effectively reduces the edge waves without altering the electronics, number of channels or beamforming in any way
- Conventional Hann apodization reduces the energy emitted from the array
- Moving the apodization to the element ends decouples the apodization from the central transducer aperture
- 3-D imaging was performed with a 64+64 CMUT array with integrated apodization

Thank you for your attention!